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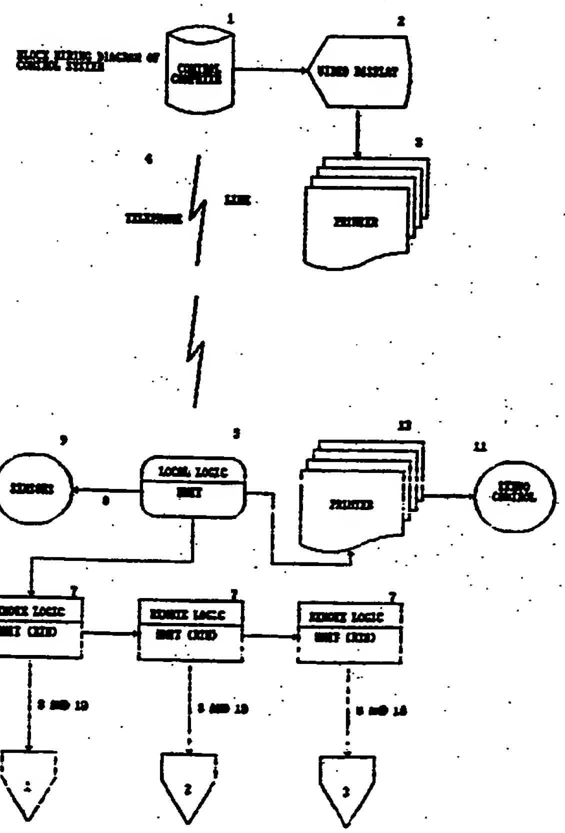
(57) Abstract

An oil/gas field system for monitoring certain characteristics in an oil and/or gas field and for controlling certain operating equipment in the field containing: a sensor (9) measuring the characteristic and for generating a signal (8) corresponding to a value of the characteristic; servo devices (11) for controlling the operation of the equipment; programmable logic (5) connected to a certain number of said sensors (9) for receiving the signals (8) of the sensors (9), the logic device (5) having outputs connected to the servo devices (11) for automatically changing the status of said equipment controlled by the servo devices when the input electrical signals are outside some allowed range remedy a non-complying condition of the equipment; and control computer remote from but connected to the logic for establishing the allowed ranges in the logic and for establishing control signals in the logic device for controlling the output of the logic device to the servo means.



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MONITORING AND CONTROL OF OIL/GAS FIELDS

Background of the Invention

The present invention relates to on site and remote monitoring and control of oil and gas operation.

Oil and gas production installations are typically monitored and controlled by installing on site standard sensor devices, such as pressure gages, flow meters, overflow indicators, vibration switches, etc. on the equipment. Operators can thus determine the status of the production equipment and wells by visually checking the sensing devices. The sensor devices connected to critical equipment are usually wired directly or through electromechanical relays to shut off control devices which can interrupt the operation of non complying equipment or shut off the whole production facility if dangerous conditions occur. During normal operation the operator has to read the various gages or sensor devices and make the appropriate manual adjustments on well valves, production equipment controls, etc. to maintain the oil or gas well or field within acceptable operating parameters.

The number of sensor and control devices is a function of the complexity of the installation, operating requirements, the prevailing operating practices of the field operator and the need to comply with statutory safety requirements.

It is relatively common, even in the simplest installations, to have a number of cut-off sensors (such as stock tank overflows, engine oil level and pressure, etc.) which disable or turn off some of the equipment or shut off the well when the parameters monitored exceed critical levels.

In more sophisticated installations the outputs of some or all of the sensor devices are brought to a central panel where the operator can monitor the operation of the field and the equipment. This avoids the need to gather information on location and the operator can perform his duties more rapidly by only going to the locations or equipment needing intervention.

A further level of automation is added when servo controls; i.e. electric motors, pneumatic activators, rheostats, etc., are added to key equipment or wells and can be activated by the operator from a remote location (i.e. the panel room) and bring the operation of the equipment into compliance. More sophisticated installations use control theory techniques and open or closed loop circuits to drive, with a function of the output of the sensor device or devices, the servo systems controlling the equipment until the value of the condition monitored returns to acceptable levels.

Much more complex and expensive monitoring control systems are also in use. SCADA (Supervisory Control and Data Acquisition) systems available commercially and utilized mostly in off-shore operations are capable of monitoring remote operations through sensors which report to a central monitoring location through a communication satellite link. In a SCADA installation the sensor and control devices must be programmed on site. In case of a non-complying condition, the output of the on location sensor is relayed, via satellite, to the central monitoring location. At the central location a processor or the human element makes a decision on a corrective action which is then relayed, again via the satellite link,

to the remote location servos.

In the present invention the outputs of commercially available or custom analog or digital sensors are connected to one or more commercially available programmable logic units. The outputs of the logic units are connected to either commercially available or custom servo mechanisms which respond to the output of the logic units as a function of the output of the sensor devices and thus can take action on the monitored equipment to comply with the preprogrammed instruction. Once the monitoring devices are connected to the inputs of the programmable logic units and the servo mechanisms are connected to the output of said programmable logic units, the operator can program both the compliance intervals for each sensor and the desired response by each servo from a commercially available control computer and software which is connected to the programmable logic units either through a telephone link or a digital data link. The programmable logic units will be capable of both monitoring and automatically correcting the non complying condition or shutting down the equipment without need of operator intervention or the need to communicate with a remote control location such as in the SCADA system. The system is thus immune from failure in the communication link and greatly improves safety and reliability. Once the programmable logic unit has taken an action, it can be programmed to report the event both on site and in the communication link to the control computer. The programmable logic unit is also capable of reporting system status on a recurring basis and log the output of all sensor devices for later analysis.

Given the almost total flexibility in the number and type of sensor devices, servo devices and the programmability of the interaction between the two sets of services, the system is capable of monitoring and controlling automatically essentially all phases of an oil or gas production facility.

Summary of the Invention

One object of the invention is to monitor the operating parameters of an oil or gas production facility and control its operation through the use of existing sensors, servo devices and programmable logic units.

Another object of the invention is to allow the operator the flexibility of changing operating parameters by making changes through a software program without need to change the hardware installation on the production facility.

A further object of the invention is to receive status reports on the operation in an efficient and economical manner.

An additional object of the invention is to be able to change the operating parameters of the installation from a remote location through commercially available software and hardware.

In the preferred embodiment, the foregoing objects are achieved by the means described below.

Sensor devices with analog output meeting the standard 4-20 mA output or on/off sensor devices are installed conventionally throughout the oil or gas production according to operating and safety requirements. The output of such devices is connected to a local programmable logic unit ("LLU") such as the Novar Controls Corporation Executive Processor or

Controller. The LIU is equipped with a number of input ports which can interface with the output of the sensor devices. As shown in Fig. 1 each sensor devices are connected to a corresponding input port of the LIU. Given the physical input bus limitation which exist in the LIU, if additional sensor devices need to be monitored, the system is expanded by connecting, via a standard RS485 connector, the LIU to one or more remote logic units ("RLU") such as the Novar Input/Output modules. The possibility of adding RLUs allows to increase the number of monitored points and the number of control devices to handle even the most complex installations.

The LIU is equipped, among others, with internal clock, ROM memories for its management and RAM memories for the acceptance of operational instructions (setting of RAM logic states) which can be, inputted, via an internal telephone module or a data link, from a control computer typically located at the home office. The control computer, such as the Engineering Support System of Novar Corporation, is a personal computer or mini computer containing proprietary interface equipment and software capable of loading the operational parameters required by the installation into the RAM memories of the LIU. In larger installations requiring RLUs, the instruction for the RAM memories of the RLUs is transferred from the control computer to the LIU RAMs which then transfers the instructions to the RLUs RAMs via the RS485 bus. RLUs can thus communicate back and forth with the LIU but not directly with the control computers.

The LLU and the RLUs can thus be programmed to perform the following function:

1.) Data Logging. The LLU and RLUs read the output of the sensor devices, store it and can transmit the data, via the communication link to the control computer. The data is also available on site through a control panel and display installed on the LLU.

2.) Fault Detection. Both the LLU and the RLUs can be programmed to detect a fault condition which exists when the output of a sensor device falls outside a preprogrammed allowable range. When a faulty or non complying condition is detected, the unit detecting the non complying signal, will respond according to the programmed instruction by activating one of its outputs connected to the appropriate servo device.

3.) Corrective Action. The local and remote logic units are capable of two types of output:

a. on/off a.c. voltage.

b. pulse modulated a.c. voltage.

The on/off a.c. voltage can be used to activate a servo, such as a shut-off pneumatic valve to shut off the well or a cut off switch to kill an engine if the non complying condition requires such action.

The pulse modulated a.c. voltage is a function of the value of the sensor output and thus can be utilized in a closed loop circuit to drive a servo mechanism which will act on the process until the sensor output has returned within the allowed operating range.

4.) Reporting Function. The local logic unit can be programmed to report to the control computer, via the communication link, either at

preset time intervals or upon occurrence of a non complying condition, the status of the system. Both the on site operator and the operator of the control computer can poll the LIU to determine system status.

Since the system does not depend on the functionality of the communication link to operate once it is programmed and all decisions are made on site by the LIU or the RIUs, reliability and safety are greatly improved.

The system capability to accept both digital (on/off) or analog inputs and to be programmed for both on/off and analog (proportional) output signals makes it possible to essentially monitor all phases of the operation and take all manners of corrective action for a total or partial operation management, as desired by the operator.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1. Is a block diagram of an installation including all types of input and output which can be included in the system.

Fig. 2 Is the representation of an actual installation in the field.

Fig. 3 Is the flow chart of the control logic activated by one of the sensors.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Fig. 1 is the block diagram of the interconnection of a typical system showing the basic system components according to the preferred embodiment. Control Computer 1 is a commercially available computer, such as the Novar Corporation Engineering Support System which contains buffer hardware and specialized software to control the system. The control computer is connected to a video display 2 and, if desired, can be connected with a compatible printer 3. Components 1,2, and 3 can be located anywhere access to a telephone line is available.

The control computer is connected, via a telephone link 4 to the balance of the system which is installed on the location to be monitored and controlled.

LLU 5, which is a commercially available logic processor, is connected, via an internal modem and link 4, to the control computer 1. LLU 5 may also be connected, via an RS485 bus 6, to one or more RLUs 7. The addition of RLU units, which are commercially available programmable logic units, such as the Novar Corporation Input/Output modules, allows the system to be expanded to handle all of the monitoring and control functions necessary in the installation.

Both the LLU and RLU units are connected, via input buses 8 with monitoring sensors 9. The sensors are installed on the equipment to be monitored. The number of sensors which can be connected to each unit is typically limited to eight. Said sensors can either be of the on/off type or commercially available 4-20 mA output analog sensors.

The LLU and RLU units are also connected via output buses 10 to servos 11. These commercially available devices can be on/off devices or proportional analog devices. The servos are also installed on the equipment. Depending on the instructions received from the LLU or the RLUs, they either shut off or alter controls or settings on the controlled equipment. The LLU may also be connected, via a data bus 12 to a local printer. 13. Once the installation is complete, the operator sets the normal operating parameters for all the operator sets the normal operating parameters for all sensors in the control computer. This sets the complying and noncomplying output range for all the sensors in the installation. Next the operator sets the desired response

for all servo units 11 as a function of the output of sensors 9. Thus the total response and interaction of sensors and servos is established. The logic level settings in the control computer are then loaded into the LLU 5 via telephone link 4. The LLU transfers the logic levels to the RLUs via data bus 6. The installation is then fully programmed and operational. The LLU and RLUs need no further instructions from control computer 1 and will perform all monitoring and controls unattended. The LLU will report system status to control computer 1 on demand or at set times, as programmed from the control computer.

Fig. 2 is the physical installation diagram of an actual system and is representative of a typical medium size installation. The installation consists of one LLU 101 and 4 RLUs (102,103,104, and 105) in Fig. 2.

The installation also includes thirteen sensors. The sensors are numbered 106 through 118 in Fig. 2.In addition the installation utilizes five servos numbered 119 through 123 in Fig. 2.

DESCRIPTION OF SENSORS

Sensor 106 is a temperature sensor which is installed at the glycol feed into the glycol tower. It is a 4-20 mA output device, such as an Omega Inc. K Thermocouple. Sensor 107 is a fluid level sensor with 4-20mA output (Omega LV1101).
Sensor 108 is a flow meter used to meter the oil delivered out of the stock tank. Sensor 109 is an overflow sensor (4-20mA output) capable of detecting when the stock tank is full and cannot store additional oil. Sensor 110 is a fluid level sensor (4-20 mA) capable of detecting the level in the salt water tank of the salt water used for injection into the formation. Sensor 111 is a pressure sensor (4-20 mA),such as Omega PX714, measuring the pressure of the water being injected into the formation. It is installed at the output of the injection pump. Sensor 112 is a 4-20 mA sensor installed in the engine lubrication loop to monitor engine oil pressure. Sensor 113 is a temperature sensor (4-20 mA), such as TX-72 by Omega Inc., installed on the treater to monitor treater temperature. Sensor 114 is a 4-20 mA overflow sensor, such as LV3001 by Omega Inc., installed on the treater to sense an overflow condition. Sensor 115 is an overheat sensor, such as TX-72 by Omega, installed on the treater to detect an overheating condition. Sensor 116 is a pressure sensor (4-20mA) installed on the treater. Sensor 117 is installed on the flare scrubber. It is a level sensor, such as LV1101 by Omega, determining the fluid level in the scrubber tower. Sensor 118 is a temperature sensor (4-20mA) measuring the

temperature of the flare.

SERVOS DESCRIPTION

Servo 119 is a 3 way mixing valve by NATCO Corp. driven by a 1/2 horsepower electric motor which can mix hot and cold glycol to achieve the desired temperature before it is sent to the glycol tower. Servo 120 is a cut off switch which shorts the magneto of the salt water pump engine. Servo 121 is a pneumatic valve installed on the wellhead which can turn the oil flow off. Servo 122 is a heater heating the treater unit. Servo 123 is a relay which drives the lighting facilities at the installation.

DESCRIPTION OF OPERATION

The operating range of the sensors and the response of the servos is loaded into the LLU and the four RLUs from the Control Computer. The operation, operating ranges for the sensors and servos' responses are as described below.

The glycol heater temperature sensor 106 is connected to RLU 102. The allowed operating range is 185F plus or minus 3F. As the temperature falls outside the normal range the electric motor of servo 119, activated by RLU 102, adjusts the 3-way mixing valve and the mix of hot and cold glycol to maintain the desired glycol temperature in the glycol tower.

Liquid level sensor 107 is connected to RLU 103 and reports an empty oil tank condition.

Turbine flow meter 108 measures the oil delivered out of the stock tank. Once delivery takes place RLU 102 monitors the delivery and the pre-loaded program converts the flow into barrels. The amount delivered is printed on site and relayed to the control computer.

Level overflow sensor 109 is installed on the stock tank and is connected to RLU 103. The RLU is programmed to allow a maximum oil level of 15ft. When the oil level exceeds the allowed maximum, RLU 103 activates the engine cut off switch 120 and water injection in the field is discontinued. RLU 104 also activates the well head pneumatic valve 121 and shuts in the well. An alarm is printed on the printer connected to the LLU 1 and the LLU informs the control computer of the condition.

The operation of the salt water injection system (secondary recovery) is monitored and controlled by the salt water level sensor 109 and pressure sensor 110. The pre-loaded program allows the tank level to be in a specified range.

If the output of sensor 110 is within the pre-established limits, the injection pump is operating. If the sensor output is outside the defined range RLU 103 will shut off the injection engine by activating shut-off servo 120 which grounds the engine magneto. Injection pressure 111 is a pressure reading servo with 4-20 mA output. The allowed pressure range in psi. is pre-programmed. If operating injection pressure is within the allowed range operations are normal. If the injection pressure falls outside the allowed range, RLU 103 again activates shut off servo 120 and gives an alarm to the operator.

The treater is monitored by four sensors; 113,114,115 and 116. Sensors monitor are all 4 to 20 mA sensors and monitor temperature, overheat, overflow and pressure. The allowed range for the temperature sensor is 147 to 150 F. At start-up RLU 104 will activate servo 122 (heater) and the heater will operate until sensor 113 has an output within the allowed range. The heater is then turned off. If an overflow or an overheating condition is detected by 114 or 115 respectively, then the heater is turned off by RLU 104 and the LLU will give a written alarm to the operator. Pressure sensor 116 monitors the pressure in the treater tank and alerts operator if pressure exceeds the preset allowed limit.

The flare scrubber has a level sensor 117. If liquid is detected above the allowed level, the well is shut in by the activation of well shut off servo 121 connected to RLU 104. The operation of the flare temperature sensor described in more detail in the description of Fig. 3.

Fig. 3 is the logic flow chart of the operation of one of the sensors, specifically the flare temperature sensor 118 of Fig. 2. The flow chart indicates the interaction between the temperature sensor, the program logic loaded in the LLU and the RLU and the applicable servos consisting of the wellhead pneumatic valve (121 in Fig 2) and the site lighting system. The flow chart details the system operation at flare start-up which is the more complicated procedure. A simplified flow chart applies during steady state operation.

At start-up the flare is ignited (Block 201). The system automatically waits for a preprogrammed period of approximately 8 minutes to allow the flare temperature to heat up (Block 202). After such time the RLU 105 to which the flare temperature sensor is connected monitors the temperature (Block 203). If the temperature is within range no further action is taken (Block 205). If the temperature is not in range the flare is pulsed and after one minute (Block 204) the temperature is monitored again by the RLU

for temperature increase (Block 206). If temperature is increasing it is checked again for proper range (Block 205) and if it is within range the system takes no further action. If the temperature is not within range the process is repeated. If temperature is not increasing the RLU activates three servos. Servo 121 (wellhead pneumatic valve) is activated and shuts the well in (Block 208). The location lights are turned on if the emergency occurs at night (Block 209) and the injection pump engine is shut off. The RLU, via the LLU also informs (Block 210) the control computer (Block 213) via telephone (212), and prints the emergency condition locally for the operator (Block 211). Similar logic flow diagrams would be applicable for the other sensors and servos.

The preferred embodiment of the invention has been described above, but variations and modifications within the spirit of the invention may occur to those skilled in the art to which the invention pertains.

WHAT IS CLAIMED IS:

1. An oil/gas field system for monitoring certain characteristics in an oil and/or gas field and for controlling certain operating equipment in the field, said system comprising:

a sensor operatively connected to the source of each of said characteristics, said sensor measuring the characteristic and for generating an electrical signal corresponding to a value of the characteristic;

servo means operatively connected to equipment related to the respective characteristic for controlling the operation of the equipment;

programmable logic means having inputs electrically connected to up to a certain number of said sensors for receiving the electrical signals of the sensors, said logic means having outputs connected to said servo means for automatically changing the status of said equipment controlled by said servo means when the input electrical signals are outside some allowed range remedy a non-complying condition of said equipment; and

control computer means remote from but electronically connected to said logic means for establishing said allowed ranges in said logic means and for establishing control signals in said logic means controlling the output of said logic means to said servo means.

2. An oil/gas field system of Claim 1 wherein said logic means comprises a remote logic unit for receiving electrical signals from up to a certain number of sensors and for changing the status of the respective

servo means when the electrical signal from the sensors is outside an allowed range, and a local logic unit operatively connected to up to a number of said remote processors and to said control computer unit, said remote logic unit and said local logic unit responding to said electrical signals by controlling the respective servo means, and said local logic unit receiving signals from said control unit for changing said ranges and for controlling the servo means, said local logic unit transmitting signals from said control computer unit to said remote logic units.

3. For use in an oil field comprising at least some of an oil well, flow line(s) running from the well to a treater tank for removing water from oil, a separator tank for holding oil to be separated from gas, flow line(s) for transferring fluid from the treater tank to the separator tank, a flare stack for igniting the gas, flow line(s) from the separator tank to the flare stack, stock tank(s) for storing oil from the well, flow lines to the stock tank(s), pump(s) for injecting liquid into the ground to aid in the extraction of oil from the well, pump(s) for pumping oil to the stock tank(s); H_2S detection means; actuation means for controlling the well(s) and the pump(s); and servo means for operating the actuation means;

a monitor and control system comprising:

sensor means, including at least some of the following:

well pressure sensor means for generating electrical signals to corresponding pressure of oil flowing from the well(s);

flow meter sensor means in at least some of the flow line(s)

for generating electrical signals corresponding to flow of oil in the respective lines;

treater pressure sensor means for generating electrical signals corresponding to the pressure in said treater tank(s);

separator sensor means for generating electrical signals corresponding to the amount of liquid in said separator tank(s);

flare stack sensor means for generating electrical signals corresponding to the temperature of the flare produced in said flare stack;

H_2S sensor means for generating electrical signals corresponding to the presence of an amount of H_2S in the gas;

pump engine pressure sensor means for generating electrical signals corresponding to oil pressure(s) in the engine of said pump;

pump gear box pressure sensor means for generating electrical signals corresponding to the oil pressure in the gear box(es) of said pump(s);

vibration sensor means for generating electrical signals corresponding to the vibration of said pump(s); and

tank level sensor means for generating electrical signals corresponding to the oil level in said stock tank(s);

programmable logic unit means electrically connected to said sensor means and to the servo means for the well(s) and the pump(s) for changing the status of the well(s) and the pump(s) in response to said respective electrical signals of said sensor means exceeding certain range values; and

control computer means electronically connectable to said logic means, means for inputting into said computer means the range values for the sensor means and the signal levels to the servo means in response to the electrical signals, and means for transferring said range values and said servo signal levels to the logic unit.

4. The monitor and control system of Claim 3 wherein said logic unit means comprises:

at least one remote logic unit connected to at least some of said sensor means and to said servo means; and

at least one local logic means operatively connectable to at least one of said remote logic units, said local logic unit transferring the range values and the signal levels to the servo means to the remote logic units, and said local logic means having display means for displaying signals from said local logic means and from said remote logic means.

5. The control and monitor system of Claim 3 and further including:

a link between said control computer system and said logic means, said link transmitting range values and signal levels for controlling the servo means from said control computer system to said logic means.

6. The monitor and control system of Claim 4 and further including printer means connected to said local logic means for printing the processed signals from said sensors.

7. A method for monitoring and controlling devices in an oil field, said devices including at least some of the following:

well(s) for the oil;

treater tank(s) for separating water from the oil;

separator tank(s) for holding the oil and gas or other liquids to be separated from the oil;

flare stack(s) for receiving and igniting waste gas;

poison gas detection means;

stock tank(s) for holding oil drilled from the ground;

pump(s) for injecting fluid into the ground to aid in the recovery of oil;

pumps for transferring oil in the devices;

flow lines connected to the various devices for an oil production system; and

sensor means connected to the respective devices for sensing and generating electrical signals corresponding to characteristics of the respective devices, the characteristics being indicative of a potentially

dangerous situation if they are outside certain range values;

servo means for controlling the operation of the respective devices;

at least one logic means connected to said sensor means for receiving the respective electrical signals from the sensor means and for actuating the servo means to operate the devices; and

control computer means operatively connected to the logic means by link means for inputting software program(s) into said logic means, said control computer means being remote from the logic means, said method comprising:

placing a software program into said control computer system for indicating ranges for the respective electrical signals from the sensor means, and for actuating said servo means when the respective electrical signals are outside their range values;

link means for transmitting the software program from the control computer means into the logic means; and

display means connected with said logic means for reading signals to said logic means.

8. A system for monitoring and controlling devices in an oil and/or gas field, the devices including equipment for drilling, processing and storing oil and/or gas, the system including:

sensor means operatively connected to the devices for generating electrical signals corresponding to characteristics of the devices;

programmable logic unit means having inputs operatively connected to the sensor means, said logic unit means having internal clock means, ROM memories for the management of the logic unit means and RAM memories for the acceptance of operational states, and outputs;

servo means having inputs operatively connected to the outputs of said logic unit means, and outputs connected to said devices for controlling the operation of the devices;

communication link means operatively connected to said logic unit means; and

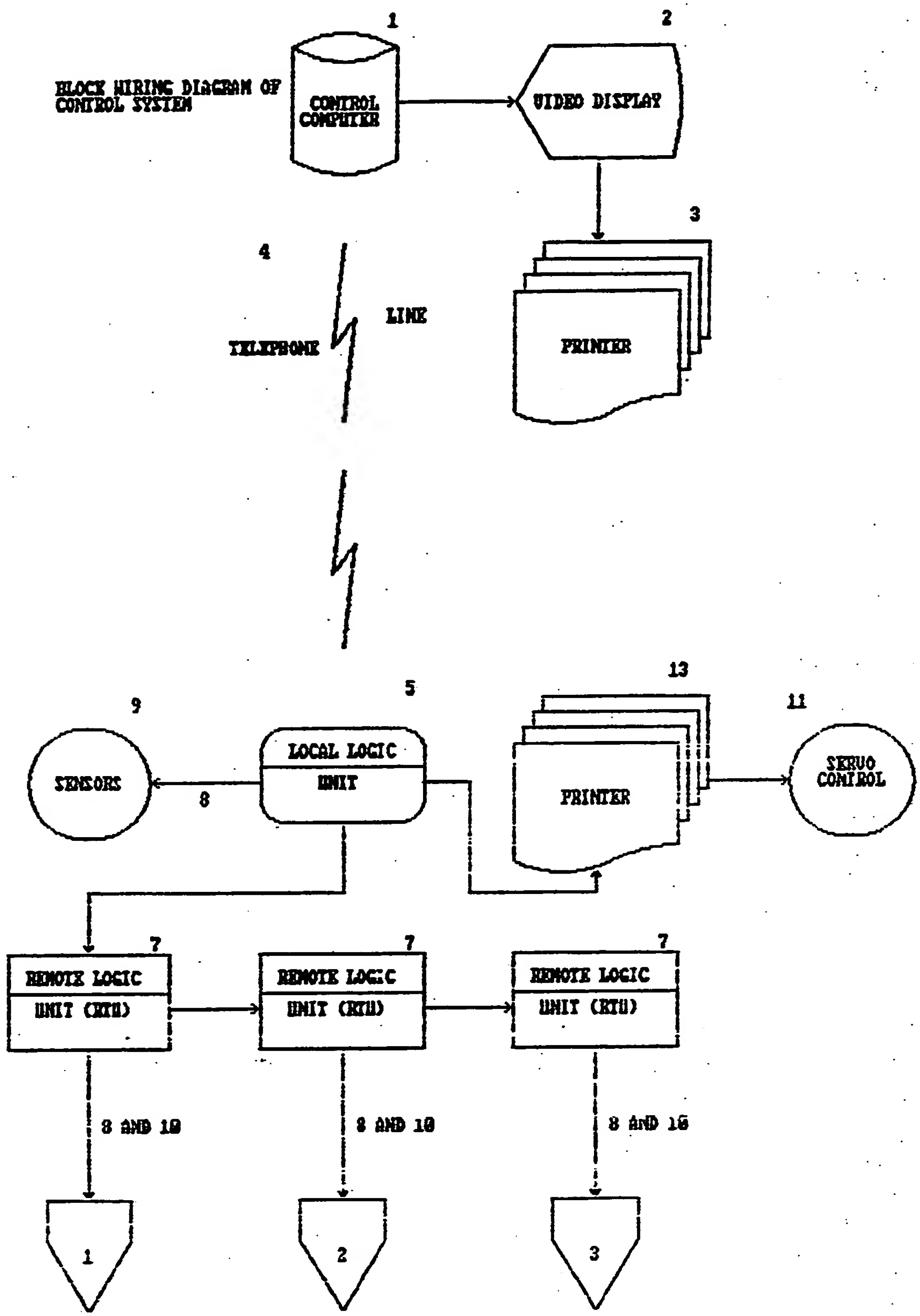
control computer means operatively connected by said communication link means to said logic unit means, said control computer means having software for receiving the operational parameters of the RAM memories and operational signal levels for the servo means and for transferring the software via said link means to said logic unit means, means for receiving the sensor electrical signals, and display means for generating intelligible signals from said received sensor electrical signals;

said logic unit means having default means for receiving electrical signals from said sensor means and for sending out operating instructions signals to said servo means to correct or shut down the devices according to the values of said sensor electrical signals.

9. The system according to Claim 8 and further including data logging means connected to said logic unit means for receiving and storing the sensor electrical signals and for transmitting said sensor electrical signals to said control computer means.

10. The system according to Claim 8 wherein said logic unit means further includes reporting means for measuring on a recurring basis the status of said sensor means and for reporting on a recurring basis said status to said control computer means.

11. The system according to Claim 10 wherein said logic unit means includes programmable remote logic unit means operatively connected to said sensor means for receiving the sensor electrical signals and for sending out operating instruction signals to the servo means, and programmable local logic means operatively connected to said remote logic unit means for transmitting operational parameters to said remote logic units and for generating operating signals to said servo means.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CONTROL COMPUTER
2
VIDEO DISPLAY
3
PRINTER
4
TELEPHONE
LINE
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LOCAL LOGIC UNIT
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SENSORS
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PRINTER
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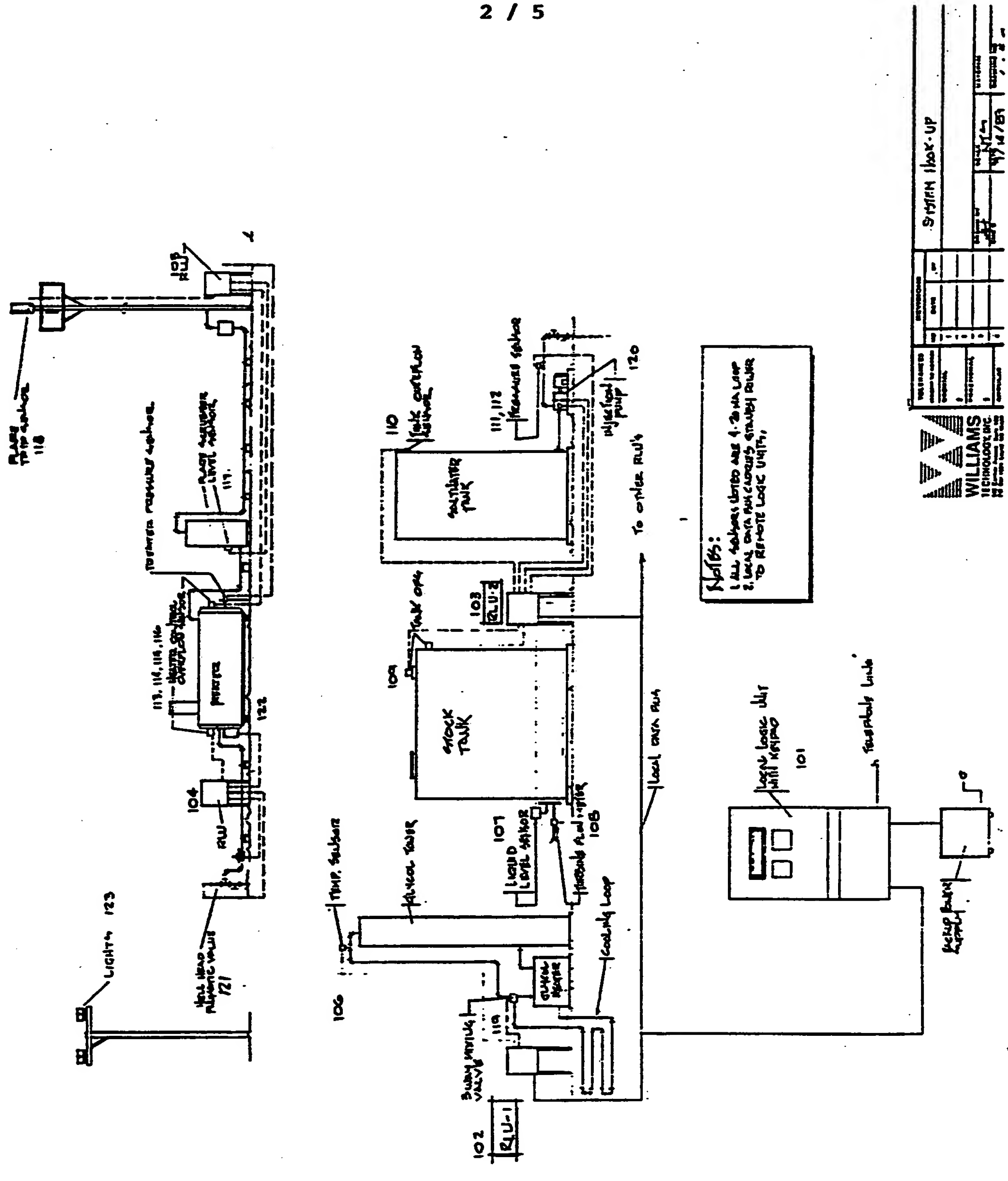

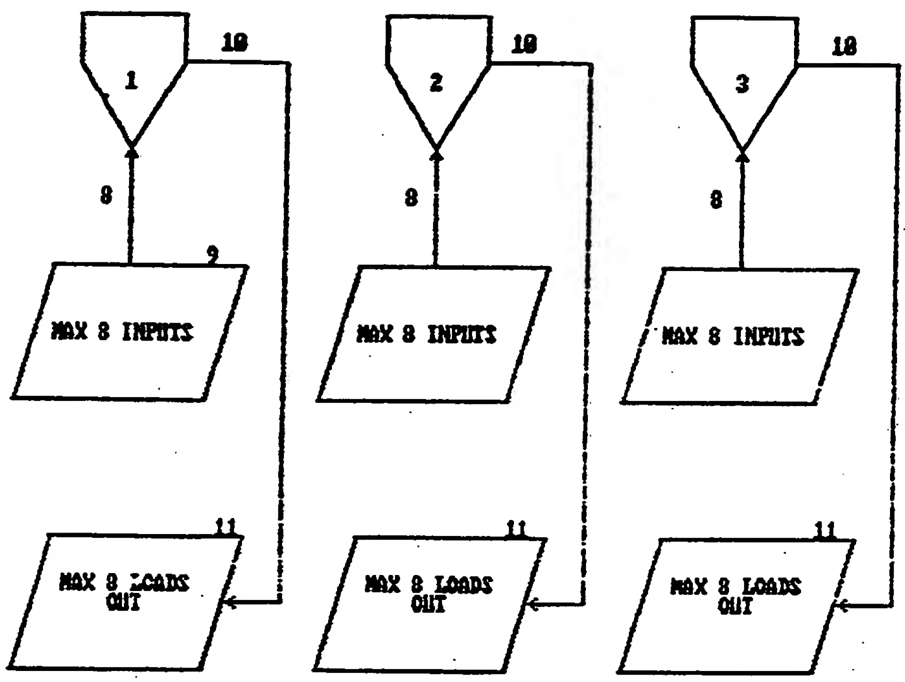
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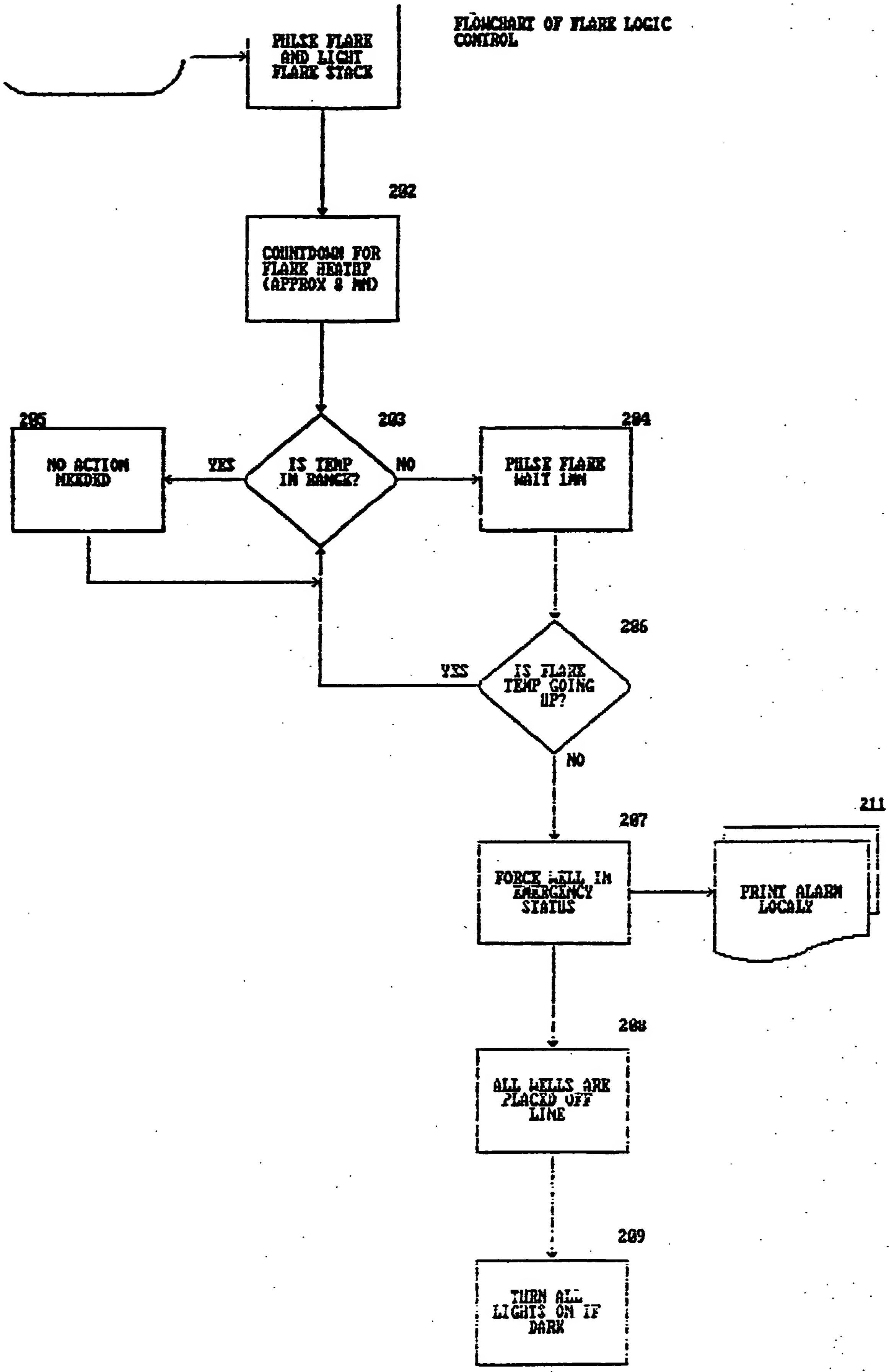
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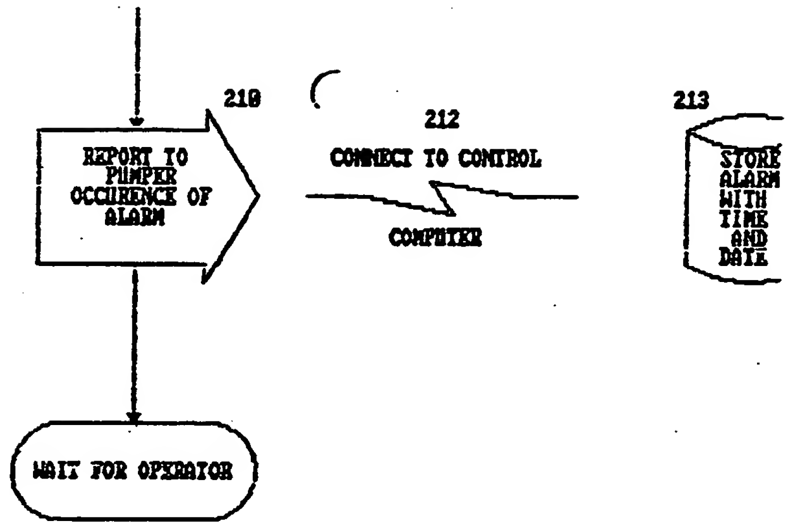
204
NO ACTION NEEDED
YES
IS TEMP IN RANGE?
NO
PULSE FLARE WAIT 1MN
206
YES
IS FLARE TEMP GOING UP?
NO
207
211
FORCE WELL IN EMERGENCY STATUS
PRINT ALARM LOCALY
208
ALL WELLS ARE PLACED OFF LINE
209
TURN ALL LIGHTS ON IF DARK


210
REPORT TO PUMPER OCCURENCE OF ALARM
212
CONNECT TO CONTROL
COMPUTER
213
STORE ALARM WITH TIME AND DATE
WAIT FOR OPERATOR

INTERNATIONAL SEARCH REPORT

International Application No PCT/US90/04003

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (5): G01B 21/00, E21B 44/00
US Cl.: 364/550, 150; 166/53

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
US	364/550, 551.01, 578, 150; 166/52, 53; 73/151

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
Y	US,A 4,794,534 (MILLHEIM) 27 December 1988 see abstract , figure 3 and brief summary	1-11
Y	US,A 4,755,925 (TSUCHIYA ET AL) 05 July 1988 see figure 2 and abstract	1-11
Y	UK,A 2,188,751 (HAWK ET AL) 07 October 1987 see figures 5 and 6	1-11
Y	UK,A 2,188,750 (DIXON ET AL) 07 October 1987 see figures 5 and 6	1-11
Y	UK,A 2,159,195 (SCHWENDEMANN ET AL) 27 November 1985 see abstract and figures 3B and 9	1-11
Y	US,A 4,150,721 (NORWOOD) 24 April 1979 see summary	1-11
A	US,A 4,413,676 (KERVIN) 08 November 1983 see entire document	1-11
A	US,A 4,402,054 (OSBORNE ET AL) 30 August 1983 see entire document	1-11
A	US,A 4,215,746 (HALL DEN ET AL) 05 August 1980 see entire document	1-11

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
09 AUGUST 1990	20 DEC 1990
International Searching Authority [1]	**Signature of Authorized Officer [20]**
ISA/US	JOSEPH L. DIXON

International Application No. PCT/US90/04003

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	US,A 4,184,205 (MORROW) 15 January 1980 see entire document	1-11

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This International search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers . . because they relate to subject matter [1] not required to be searched by this Authority, namely:

2. ☐ Claim numbers ...... , because they relate to parts of the International application that do not comply with the prescribed requirements to such an extent that no meaningful International search can be carried out [1], specifically:

3. ☐ Claim numbers__________, because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:
4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.